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Riparian vegetated margins and small mammal communities: Implications for agri-environment schemes

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Abstract
Small mammals play a vital role in agricultural ecosystems and influence the diversity and abundance of avian and terrestrial predators. Increasing small mammal populations on farmland is important for improving the biodiversity of agricultural ecosystems.
This study assessed the small mammal communities associated with 42 riparian margins in the south-east of Ireland. Riparian margins were separated into those dominated by grassy, scrubby or woody vegetation. Results suggested that riparian margins dominated by woody vegetation had the greatest abundance of small mammals. Significantly more small mammals were captured in woody habitats as opposed to grassy or scrubby habitats. Although they had the greatest abundance of small mammals, woody habitats showed the least diversity, with the small mammal community consisting almost entirely of woodmice.
Results from this study suggest that current Irish agri-environmental measures, which can lead to succession of vegetation and result in scrub and wood dominated margins, do not promote small mammal diversity in riparian margins. Current prescriptions are not providing optimal habitat for protected species such as the pygmy shrew.
Future agri-environment measures should promote heterogeneity of watercourse margins, which in turn will enhance small mammal abundance and also their diversity.

Key Index Words: Agriculture, agri-environmental measures, habitat, small mammals, watercourse margins.

Introduction

Intensification of agriculture over the last number of decades has led to a dramatic change in agricultural production methods. This in turn has resulted in a loss of ecological heterogeneity (Petit and Firbank, 2006) and contributed to the loss of diversity of wild flora and fauna (Robinson and Sutherland, 2002; Benton *et al.*, 2003). Much research has been undertaken assessing the impact of land management on a variety of taxonomic groups (Birds - Anderson *et al.*, 2001; Tucker and Heath, 1994; Flora - Hopkins and Hopkins, 1994), Invertebrates - Rushton *et al.*, 1989; Purvis and Curry, 1981). Little research has, however, been undertaken relating to the impact of agricultural intensification on small mammal communities.

Protection of uncultivated field margins, hedgerows, ditches and watercourse margins is vital to ecosystems, because they are an increasingly important source of seed and invertebrate food (Wilson *et al.*, 1999). Small mammals on farmland are largely confined to these areas of non-crop habitat and are therefore particularly vulnerable to agricultural intensification (Bates and Harris, 2009). Robinson and Sutherland (2002) stated that agricultural intensification in Great Britain led to a decrease in abundance of small mammals.

Small mammals are rarely the focus of agriecology studies because they are generally considered to be agricultural pests causing damage to agricultural products (Santini, 1977). Although some small mammals can cause significant damage to agricultural crops (Brown *et al.*, 2007), it is equally important to note that small mammals play an important role in agricultural ecosystems and contribute significantly to the complexity of food webs (Korpimaki and Norrdahl, 1991). Almost every terrestrial and avian carnivore, to some degree, depends on a small mammal prey base (Michel *et al.*, 2006). In an Irish context, small mammals constitute the main prey biomass that influences the diversity and number of predator species such as kestrel *Falco tinnunculus* and merlin *Falco columbarius* (Birds Directive 79/409/EEC Annex I species) and small carnivorous mammals such as pine marten *Martes martes* and stoat *Mustela erminea* (Bern Convention, Annex III species, see Anon. 1979). In Ireland, the woodmouse *Apodemus sylvaticus* is the primary prey item of the Red-listed barn owl *Tyto alba* (Glue, 1974).

From a habitat composition perspective, small mammals help disperse mycorrhizal fungi (Terwillinger and Pastor, 1999) whilst they also affect plant composition, tree regeneration and soil fertility through selective herbivory and seed dispersal (Hayward and Phillipson, 1979; Sirotnak, 2000). Furthermore, some rodent species contribute to the control of insect species (Parmenter and MacMahon, 1988), with a small mammal community of shrews and rodents consuming up to 6800 preys ha^{-1} day^{-1} (Churchfield and Brown, 1987).

It is therefore evident that small mammals play a significant role in ecosystem functioning and as such a number of species are protected under European legislation (Bern Convention, Annex III), whereby countries must *"take appropriate and necessary legislative and administrative measures to ensure the protection of the wild fauna species"*. One method of protecting faunal species and their habitats is through the inclusion of specific measures in agri-environmental schemes.

The Rural Environmental Protection Scheme (REPS) was initiated in Ireland in 1994 as the Irish Government's response to the EU Agri-environmental Regulation (90/207 88/EEC). In conjunction with a suite of measures, current REPS guidelines require participant landowners to leave a 1.5 m margin adjacent to all watercourses, which must be fenced to prevent bovine access to the watercourse. Prescriptions under the new Agri-Environment Options Scheme (AEOS) require margins to be fenced between 2.5 m and 30 m from the watercourse (depending on the options selected). Application of agricultural inputs such as fertilisers, herbicides and pesticides must be restricted within this fenced area. No further management of these fenced areas is required. The aims of such a fencing policy are two-fold: a) to improve water quality by preventing cattle from disturbing the streambed and banksides, thus reducing inputs of sediment and organic material to a watercourse and b) to enhance the biodiversity of riparian habitats and of the wider agricultural landscape.

Although these fenced sites are seen as potential refuges for biodiversity, little information exists in relation to the effect of the succession of the streamside margin vegetation on small mammal communities. Fencing of watercourse margins and the resultant absence of grazing can give rise to natural succession of vegetation from grassy (primarily herbaceous species) to scrubby (e.g. bramble, gorse) to woody (e.g. alder, willow) vegetation (Ockinger *et al.*, 2006).

Watercourses and their margins contribute significantly to the heterogeneity of agricultural ecosystems; however, relatively little information exists on the use of riparian buffer strips by terrestrial species. Buffer strips have the potential to support a rich and abundant small mammal community (Chapman and Ribic, 2002). However, how these strips are managed is of great importance. Management that reduces vegetation height and removes cover (and the food associated with this cover) can result in a reduction in rodent numbers (Jacob, 2003; Lemen and Clausen, 1984). Furthermore, a reduction of cover exposes small mammals to increased predation (Stamp and Ohmart, 1978; Preston, 1990).

There are five species of small mammal in Ireland: woodmouse (*Apodemus sylvaticus*), house mouse (*Mus musculus*), pygmy shrew (*Sorex minutus*), bank vole (*Clethrionomys glareolus*) (an introduced species, Claassens and O'Gorman, 1965) and greater white-toothed shrew (*Crocidura russula*), a species discovered in Ireland for the first time in 2008 (Tosh *et al.*, 2008).

The aim of this study was to assess the impact of riparian margin vegetation type on small mammal communities in Ireland. It is envisaged that the results garnered in this study could help inform policy makers when designing future agri-environment management prescriptions aimed at enhancing biodiversity in watercourse margins.

Materials and Methods

Study area

The study took place on a number of sites in County Wexford in 2007. County Wexford is situated in the south-east of Ireland, between 52° 7' and 52° 48' north latitude and 6° 8' and 7° 1' west latitude. Agriculture is the dominant land use in Ireland, accounting for 65% of the land area, with over 90% of this agricultural land devoted to grass production (Fingelton and Cushion, 1998). Within the study area, pasture was the dominant land-use. Soils in the study area are predominantly loamy and clayey.

Average daily temperature for Wexford (Johnstown Castle) in 2007 was 10.9°C, maximum temperature was 23.6°C and total rainfall was 889 mm. The results in this paper are based on three sampling sessions in 2007, one in early summer (May; average temp 11.8 °C, maximum temp 23.6°C and total rain 54.5 mm), one in late summer (August; av. 15.2 °C, max. 22.7°C, 104.4 mm) and one in winter (December; av. 7.3°C, max. 13.3°C, 85.5 mm).

A total of 42 sites were selected (14 grassy, 14 scrubby and 14 woody). Each site was dominated by either grassy vegetation, scrubby vegetation or woody vegetation. Grassy sites were dominated by gramineous plants such as *Lolium* and *Agrostis* and by forbs such as *Cirsium arvense* and members of the *Ranunculaceae*, *Polygonaceae* and *Leguminosae* families. Scrubby sites (vegetation less than 2 metres in height) were dominated by *Ulex europaeus*, *Rubus fruticosus*, *Pteridium aquilinum*, *Alnus glutinosa*, *Prunus spinosa* and members of the *Umbelliferae* family. Woody sites (vegetation above 2 metres in height) were dominated by *Crataegus monogyna*, *Fraxinus excelsior*, *Hedera helix*, *Ilex aquifolium, A. glutinosa* and by members of family *Salicacea*.

Land use adjacent to the sampling sites was primarily pasture for cattle, with a small number of sites also containing sheep and/or horses.

All watercourses selected for the study were between 1 m and 3 m in width and flowed for at least 9 months of the year. A 30 m stretch of watercourse margin was selected for study at each site.

Mammal surveys

Sites were sampled using Longworth traps (standard live-traps used for small mammal field studies, Gurnell and Flowerdew, 2006). A standardised protocol, after Hansson (1967), was followed. Traps were baited with peanuts and minced meat (to provide food for insectivores and herbivores). Hay was provided in the nest box for bedding. The treadle weight was set to facilitate the capture of juvenile rodents and shrews as well as adults. Traps were placed in pairs every 10 m in trap lines, at distances of 1 m and 5 m from the stream edge. Therefore, each 30 m section of margin contained 16 traps. Traps were left *in situ* for two nights during each sampling session and inspected at dawn, dusk and at least twice during the day.

Captured mammals were identified to species. Only three of the five species of small mammal found in Ireland are found in relatively large numbers in the study area (woodmouse, house mouse and pygmy shrew). Of the remaining two species, the bank vole, although long established in the south west of the country, is typically absent from large portions of the rest of the country. The greater white-toothed shrew has only been recorded in Tipperary and Limerick (in the south west of the country) (Tosh *et al.*, 2008).

Captured mammals were marked by fur clipping. Different parts of the body were clipped to denote where the animal was captured. Animals were weighed using a spring balance and weight was recorded to the nearest gram. Sexual characteristics were used to denote the sex, age group and breeding condition of the animal. Callipers were used to record the length of the hind tarsus of the animal (an indication of general body condition).

Data analysis

Small mammal abundance was the total number of small mammals captured and species richness was the number of species captured.

Abundance data were analysed using SAS 9.1 (PROC GENMOD). Capture data were zero-inflated and the data were overdispersed. A Poisson regression with random side effects and log-transformed data were selected to account for this. The results were analysed using split-plot in time analysis. A split-plot design is useful when one factor is applied to a larger experimental unit (main-plot), and another factor is applied to smaller units (sub-plot) within the larger experimental unit (Littell *et al.*, 2005). Specifically, in this study, *Habitat* was the main-plot factor, and *Distance from Stream* was one of the sub-plot factors.

Shannon's Index (Zar, 1999) was used when assessing the species diversity of each habitat. Hutcheson's test (1970) was used to compare diversity indices between habitat types. The magnitude of the Shannon Index is affected by both the distribution of the data, and also the number of categories (Zar, 1999), which in this study was low. To account for this, the "Relative Diversity" (J') was calculated, alternatively, "Dominance" (1-J') was also included.

Results in relation to the weight and tarsus length of small mammals (woodmouse) were analysed using ANOVA and PROC GLM.

Results

The results in this paper are derived from 4,032 trap nights in 2007. A total of 317 captures occurred, of these, 90.5% were woodmouse, 7.6% were pygmy shrew and 1.9% were house mouse (Table 1).

The results (Table 1) showed that there was a significant habitat effect ($P < 0.01$): Significantly more mammals were caught in woody habitats as opposed to scrubby or grassy habitats (Table 1). Figures in Table 1 in relation to grassy and scrubby can appear slightly misleading in that a high number of traps in grassy margins captured non-target species (in particular slugs, which is not uncommon in longworth trap studies), thus leaving them unavailable to capture small mammals. When this information was included in our statistical analysis, traps located in scrubby habitats had a lower success rate than those in either grassy or woody sites.

Distance from stream was an important factor, with significantly ($P < 0.0001$) more mammals being caught within 1 m of the stream as opposed to 5 m.

Sampling period (early summer, late summer and winter) was also significant ($P < 0.05$) with more small mammals being caught in winter than in either early or late summer.

Diversity analysis (Shannon index, Hutcheson's test) of the results in Table 1 showed that although abundance of small mammals was greatest in woody habitats, these sites were the least diverse ($P < 0.01$). Grassy habitats showed highest diversity with the small mammal community consisting of 78% woodmouse, 19% pygmy shrew and 3% house mouse, whereas the communities of woody habitats were dominated (98%) by woodmice.

Additional data were collected in relation to woodmice biometrics. Only data relating to adult woodmice ($n = 264$) are used in this article. The numbers of pygmy shrew and house mouse collected were too low to accurately reflect impact of habitat type on biometrics. Both sex and breeding condition had a significant effect on the weight of adult woodmice (Table 2). Males were significantly heavier than females ($P < 0.001$) and breeding woodmice were significantly heavier than non-breeding mice ($P < 0.001$). This latter point is not surprising considering that during the breeding season, the genitals swell to many times their non-breeding weight (Gurnell and Flowerdew, 2006) thus influencing the overall body weight.

The habitat effect was not significant ($P = 0.627$), however, when individual habitats were compared, woodmice captured in scrubby habitats weighed significantly less than those in both grassy and woody habitats ($P < 0.05$).

Results from data collected in relation to weight and tarsus length suggested that there was a significant correlation ($P < 0.001$) between the weight of an adult woodmouse and the length of its tarsus. Both measurements are typically used as an indicator of fitness.

Table 1: Small mammal captures in watercourse margins.

	Grassy	Scrubby	Woody
Woodmouse	58	97	132
Pygmy Shrew	14	7	3
House mouse	2	4	0
No. caught at 1 m	63	54	108
No. caught at 5 m	11	54	27
Total capture	74	108	135
Shannon (H')	0.26[a]	0.17[a]	0.05[b]
Relative diversity (J')	0.548	0.360	0.096
Dominance (1-J')	0.452	0.640	0.904

[a] Indices followed by identical letters did not differ significantly (Hutcheson's test).
Grassy v Scrubby $t_{0.05(2), 172} = 1.729$; $P = 0.085$
Grassy v Woody $t_{0.05(2), 120} = 5.005$; $P < 0.01$
Scrubby v Woody $t_{0.05(2), 177} = 3.022$; $P < 0.001$

Table 2: Adult Woodmouse weight (g) and tarsus length (mm).

	Grassy			Scrubby			Woody		
	n	Mean	S.D	*n*	Mean	S.D.	*n*	Mean	S.D.
Female Weight	*21*	21.143	3.021	*40*	20.600	3.650	*48*	20.809	3.780
Male Weight	*27*	25.393	3.224	*54*	22.556	4.355	*74*	23.811	4.229
Total Weight	*48*	23.571	3.764	*94*	21.723	4.164	*122*	22.644	4.303
Female Tarsus	*21*	13.029	0.263	*40*	12.750	0.473	*48*	12.762	0.489
Male Tarsus	*27*	13.436	0.573	*54*	13.122	0.653	*74*	13.214	0.452
Total Tarsus	*48*	13.261	0.505	*94*	12.964	0.609	*122*	13.038	0.514

Discussion

Small mammals play an important role in agricultural ecosystems, and measures that enhance their abundance and diversity should be promoted. Increased small mammal populations on farmland are crucial to improving the biodiversity of agricultural ecosystems (Bates and Harris, 2009).

Agri-environment schemes, incorporating measures that protect non-crop habitats, are seen as an important tool in halting biodiversity loss (as per the target of the Rio Convention on Biodiversity). The Rural Environmental Protection Scheme and the AEOS are seen as opportunities to protect non-farm habitats such as watercourse margins and promote the biodiversity associated with these habitats. REPS Measure 3 and the Riparian Margins Option in the AEOS stipulate that farmers must fence all watercourse margins (to prevent bovine access) and to allow natural vegetation to develop. It is envisaged that such fencing will improve biodiversity by attracting a wide range of flora and fauna.

Results from the present study indicate that the habitat type that develops in riparian margins has a significant impact on abundance and diversity of small mammals. Riparian margins dominated by woody vegetation contained a significantly more abundant small mammal community than grassy or scrubby margins; however, this community was made-up almost exclusively of one species (woodmice).

Results in this study correspond to those of Montgomery and Dowie (1993) who found that woodmice are by far the most common small rodent associated with field boundaries in Ireland. Abundance and dispersion of woodmice is related to food supply (Montgomery *et al.*, 1991). As stated previously, woody habitats in this study were dominated by trees such as Ash and Hawthorn, both of which provide substantial quantities of seed for woodmice. Grassy habitats (dominated by grasses and forbs) do not provide the same amount of food for woodmice, nor do they provide the same cover, and hence support a lower abundance of woodmice. Grass dominated sites do however support an abundant invertebrate community and therefore proved to be a more suitable habitat for insectivores such as the pygmy shrew.

The varied food supply associated with grassy habitats helps explain the greater diversity of small mammals. These results correspond to those of Geier and Best (1980) who found that the most diverse small mammal communities were found in channelised grassy habitats along streams which experienced minimal disturbance from grazing, haying and herbicides. Similarly, Butet *et al.* (2006) found that grass-dominated habitats at field boundaries result in a lower abundance of small mammals but promote a more balanced diversity of the community.

These results highlight the importance of targeting within agri-environment schemes, as discussed by Kleijn and Sutherland (2003).

For example, woody habitats could result in a greater abundance of small mammals and therefore provide a greater food-source for avian and terrestrial predators. However, under the Bern Convention we are obliged to protect small mammals such as the pygmy shrew, and therefore grassy margins are also required.

Results from this study indicate that scrub dominated habitats had the lowest abundance of small mammals. Once again this is largely due to the availability of suitable food. Habitats dominated by species such as gorse, despite providing excellent cover for small mammals, provide considerably less of their favoured food than many woody sites (Montgomery *et al.*, 1991). This explanation is given further credence by the fact that animals found in scrub, weighed significantly less than those found in either grassy or woody habitats ($P < 0.001$). In relation to insectivores, species such as the pygmy shrew are dependent on moist habitats (Hutterer, 1990), and are typically found in habitats with abundant ground vegetation cover (Churchfield, 1990), both of which are associated with grassy margins. Scrubby vegetation, frequently dominated by gorse in the current study, and the resultant shading it gives rise to, typically results in poor establishment of ground flora and therefore does not offer a moist habitat nor does it offer abundant ground vegetation. In the current study, the majority of pygmy shrews that were caught in scrubby vegetation were caught in scrub dominated by *Prunus spinosa* and members of the *Umbelliferae*, as opposed to scrub dominated by gorse.

The house mouse was rarely recorded in the current study. This is not surprising since *M. musculus* is rarely abundant in cultivated fields (Kaufman and Kaufman, 1990).

Sampling session had a significant effect ($P<0.05$) with significantly more small mammals being caught in winter than in either early or late summer. This is largely due to the fact that woodmice are less territorial in winter and must also cover a larger area if sufficient food is to be found. A larger forage area results in a greater likelihood that small mammals will come into contact with the traps and hence a higher rate of capture.

Significantly more ($P < 0.05$) small mammals were found adjacent to the stream as opposed to at a distance of 5 metres from the stream edge. These results support the findings of Chapman and Ribic (2002) who found that small mammal abundance was greater near the stream than away from the stream. This was particularly evident in grassy and woody habitats. This is probably due to differences in sward structure between sites adjacent to the stream edge and those at a 5 m distance. Current agri-environment regulations state that fences must be erected 1.5 m to 30 m from the stream edge. Such fencing results in a greater sward cover, and hence is a more suitable habitat for small mammals. A reduced sward cover results in less food being available and also exposes small mammals to the risk of predation. It is however important to prevent the sward cover from becoming dominated by scrubby and subsequently woody vegetation if species such as the pygmy shrew are to be protected.

The results in this study indicate that current watercourse margin management prescriptions, which include fencing and the resultant succession of vegetation, are not promoting small mammal diversity and are not providing a suitable habitat for pygmy shrews (Bern Convention, annex III species). Fencing, with no additional management of the margin, allows species such as *U. europaeus* to dominate the habitat, thus resulting in a less suitable habitat for small mammals, and in turn impacting on the diversity of the ecosystem. Furthermore, current REPS prescriptions are not promoting structural diversity, which is an important factor for both vertebrate and invertebrate abundance and diversity.

It is important that the measures aimed at enhancing the biodiversity value of watercourse margins promote heterogeneity of habitats. Maisonneuve and Rioux (2001) highlighted the importance of maintaining a diversity of riparian strips in order to maintain high wildlife diversity within agricultural landscapes. They stated that having a suitable ratio of grassy, scrubby and woody habitats helps maintain the highest possible diversity within agricultural ecosystems. A number of studies (Maisonneuve and Rioux, 2001; Sullivan and Sullivan, 2006) found that abundance and diversity of small mammal communities were highest in those habitats where species and structural diversity of vegetation were highest, thereby providing a range of microhabitats. Efforts to integrate the conservation of riparian strips in the management of agricultural lands should lead to both agroecosystems and environments of increased habitat quality.

Conclusions

The current REPS and AEOS guidelines of fencing all watercourse margins, and the subsequent vegetation succession it gives rise to, is not promoting small mammal diversity within these habitats. Maintaining a diversity of riparian vegetation is vital to maintaining high wildlife diversity within agricultural landscapes. It is likely that periodical cutting, seasonal grazing or alternative managements of margins would promote heterogeneity of habitats and in turn result in a greater diversity of small mammals and of floral and faunal communities in general.

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